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ABSTRACT

Estimates calling for 1.2 million computer-assisted design (CAD) operator positions to be available by 1990 have prompted educational institutions throughout the country to incorporate instruction in CAD into their industrial arts curricula. Therefore, the question for schools is not whether to buy but rather what to buy. An effective strategy for purchasing CAD software should include the following steps: formation of a selection committee, comprehensive research on the concepts of CAD, formulation of a rationale for purchase, consideration of at least 15 points before selecting a CAD system, and negotiation with several vendors once a CAD system has been chosen. There are three approaches to establishing CAD competencies in any drafting setting. Instruction in CAD can be introduced (1) after students have developed proficiency in manual skills and a drafting discipline, (2) by establishing competency in a drafting discipline using computers instead of drawing boards, or (3) by first establishing an elementary competency in a drafting discipline using freehand sketching and then using CAD and manual skills together for industrial-quality work. Regardless of the integration method chosen, students working with CAD software need to develop prerequisite competencies in basic programming, trigonometry and analytical geometry, and a drafting discipline. (Appendixes to this report include lists of publishers of recommended course materials and microcomputer CAD software vendors, a form for evaluating CAD systems, and a directory of microcomputer CAD systems for education.) (MN)

Computer Aided Design in the Classroom

A paper presented at the

American Vocational Association Annual Conference

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by

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INTRODUCTION

There is no question that computer-aided design has found its place in the backbone of American industry. As the interface between man and machine, CAD serves to integrate the maximum capabilities of each to rise above the manual drafter in applying the concepts of engineering graphics. Industry realizes the benefits of CAD; this can be seen in a 1985 study by Arthur Neilsen of Vincennes University. His study found that sixty percent of local industrial CAD users are devoted to CAD 100%. His study also unveiled that sixty-five percent of interviewees stated that students should learn one type of system. Groves, in his article "Selecting a CAD System" stated "Rest assured, the revolution taking place in drafting is real. In fact, business and industry are converting to CAD faster than once projected. The growing demand for CAD operators reflects this conversion--with an estimate that over 1.2 million new jobs will be created by 1990. In response, educational institutions must quickly incorporate CAD instruction into various vocational/technical and engineering areas (Groves, 1984)."

Much of the initial educational response came from the university level. In 1978 a conference of the Deans of the Colleges of Engineering at the Big Ten Universities indicated "The urgent need for development of computer graphics as a key element in engineering curricula." (Thorsen, Lee, Wei, 1985). Since that time the University of Illinois has integrated the IBM PC based AutoCAD into the engineering curricula. Purdue University starts their students on the Apple microcomputer based MATCCAD before turning them loose on the 1.3 million dollar Computervision main-frame system. Colorado State University has implemented a CAD course using AutoCAD (Wohlers, 1984). At Indiana State University, the Industrial Technology Education department uses Apple IIE based MATCCAD and CADApple software for experimentation by students;

the Manufacturing and Construction, and Industrial Mechanical departments are preparing to release AutoCAD for use by the student population to expand upon the 4 minicomputer based Medusa CAD workstations. However, educators must realize that many apprentice drafters are not college graduates. They are products of the secondary industrial vocational and technical system. Who will address these students?

In October 1985, Purdue University held a "CAD awareness conference" to orient Indiana technical teachers to the oncoming technology. The response was overwhelming as more than 100 technology teachers attended. Many of these teachers had not been introduced to the concept and terminology of computer aided design, nor to the hardware utilized by a CAD system. But the interest, enthusiasm, and determination were present. The need was clear; information and advice must be made available to technology teachers concerning the implementation of computer aided design into their curriculum.

The following information is the compilation of many references, and is intended to provide both depth and breadth into the fascinating technology of computer-aided design, especially as it relates to the secondary technology curriculum.

CAD DEFINED

Before we can proceed, a common definition of computer-aided design must be laid down. Groover and Zimmers stated that "computer-aided design can be defined as the use of computer systems to assist in the creation, modification, analysis, or optimization of a design (Groover and Zimmers, 1984:1)." M. Zandi stated that computer-aided design is "the interactive use of digital computers to carry out the tasks of design and drafting (Zandi, 1985:3)." Gary Bertoline defines CAD as "the use of computers, software, and

associated hardware to produce drawings that would normally be prepared manually (Bertoline,1985:6)." All of these definitions point out key terms that would go into a common definition of CAD.

CAD systems use computer systems to to replace the tools of manual drafting used to assist the drafter. The key word is assist. The computer system does not draw the design for the drafter, although artificial intelligence is increasing that possibility. At this time, the CAD system is only a tool, as are a pencil, triangle, and eraser. The manual drafter uses a pencil to draw a line. A CAD operator uses an input device (keyboard, mouse, digitizer) to enter the endpoints of a line, and the computer completes the line. The manual drafter corrects his/her mistakes with an eraser. A CAD operator corrects mistakes by pointing to a line (cirlce, arc, etc.) to be erased, and it is erased. The manual operator draws on a sheet of paper. A CAD operator designs using the screen (cathode ray tube--CRT) until his/her drawing is complete, then plots the drawing using a plotter.

The benefits of a CAD system derive from the fact that a CAD system records a drawing with information in the computer, not with lead on a piece of paper. The difference is the medium of creating a design, and because a computer can manipulate large amounts of information in a short time, the CAD operator can also create, edit, and plot a drawing in a shorter amount of time than can a manual drafter.

THE BENEFITS OF CAD/CAM IN INDUSTRY

The computer's capability to manipulate large amounts of information involved in a drawing brings about many benefits over manual drafting. The first of these benefits is productivity.

The number of drawings produced in a given time is significantly higher

in firms using CAD systems. This is due to enhanced visualization of the object being designed, reduced time in synthesizing, analyzing, and documenting the design, and the simple fact that use of a CAD system is faster than manual manipulation. There are some dependencies that can affect the magnitude of productivity. The more complex, detailed, symmetrical and repetitive the drawing is, the more significant a CAD system can be. A CAD system can mirror one half of symmetrical drawing or make multiple copies of a part to be used many times in a particular drawing.

Where improvement in the quality of the design is concerned, a CAD system provides for a more thorough analysis of the design through application programs such as finite element analysis, mass properties analysis, ergonomics, simulation of machine tool paths, etc.

Improving communications and standardization, the use of a CAD system provides for standardization of documentation, lettering, greater legibility, and reduced drawing errors. Communication is enhanced through networking of the entire system for communication between management, designer, manufacturing engineer, and production supervisor.

A CAD system also provides for quicker customer modifications. Should a design need modifications, the drafter can bring the drawing out of memory, quickly change the required entity, and replot the design. This often can be done within an hour (Groover and Zimmers, 1984).

Finally, since a CAD system stores numerical information about the drawing in memory, the draftsman can analyze the properties of the part being designed. This often eliminates the need to make a manufacturing prototype since testing is simulated on the CAD system.

CAD PURCHASING STRATEGY

Introduction

The estimate that 1.2 million CAD operator positions will be available by 1990 prompts educational institutions to incorporate CAD into the industrial arts curriculum. Therefore, the question is not "whether to buy", but rather "what to buy." The purchase of a CAD system is not, by any means, a simple process. Vendors often confuse the client with conflicting claims of system capabilities. The following purchasing strategy is not all inclusive, but rather a sound beginning in the selection and purchase of a computer-aided design system.

Selection Committee

The selection of a CAD system is a task that should not be performed alone. Consider an administrator, computer faculty, a representative from industry and/or a nearby university, and the technology faculty members who will be using the system.

Once organized, the beginning task of the selection committee is to gain a general knowledge about CAD.

Researching the Concepts of CAD

It is advisable to know the fundamentals of computer-aided design to determine the CAD system's utilization as related to desired educational goals and objectives. The collection of information can be obtained from a variety of sources, including conferences, seminars, local colleges, professional magazines, trade shows, books, and vendor literature.

A list of textbooks, media, and professional jounals concering CAD are provided in Appendix A.

Rationale for the Purchase

Although many administrators are supporting purchases of CAD systems, there may be be questions. "Why do we need it?" "Can't you use existing computers?" "Won't industry supply you with something?", etc. Check available industrial, education, governmental and private resources for funding. Make sure your stance reflects industrial needs, and the objectives given for the CAD system are compatible with the mission of your department.

Selecting a CAD System

Before talking to vendors, develop an evaluation chart to compare essential features among different CAD systems. One such chart was used in evaluating CAD systems in the March 11, 1986 edition of PC Magazine. An edited replication of this chart including features identified by Tony Weber of Gregg/McGraw Hill is found in Appendix B. Considerations are dependent upon the desired level of skill development your students need. Are the students being trained for industry standards or as a general orientation. As a rule, due to cost, educators use simulation equipment. It is also advisable to assess computers already owned by the school which could be used by the industrial education department for CAD work. A listing of microcomputer based CAD systems to look into is located in Appendix C.

Considerations when dealing with vendors include (Schwendau, 1984)

1. What courseware is available?
2. Are software updates included in the cost?
3. Is there a warranty and maintenance contract? What does it cover?
4. Where does the system go for repair?
5. Is there a training course for teachers? Cost?
6. Does the price include everything needed for operation? (cables, interfaces, operators manual)
7. Can backup copies of the software be made?
8. Does the vendor have any educational affiliations?
9. Is the vendor financially stable?
10. Does the sales representative have drafting background?
11. Are other customers happy with their service?
12. Does the local division vendor take care of all service?
13. Is there a local application specialist?
14. Is there an emergency hotline?
15. Who installs the system.

Making the Final Purchase

Once the systems and vendors have been researched and a desired system chosen, it is appropriate to negotiate with different vendors. Computer prices are flexible, especially for larger purchases made by a school system or district. The key point is to not rush into a purchase. Take into account the information obtained from the previous steps and direct this knowledge toward selecting the best CAD system for the school's particular educational needs.

CAD IN THE CLASSROOM

Teaching Methodolgy

There are three approaches to establishing CAD competencies in any drafting setting. The most common integration of CAD appears after students have developed proficiency in manual skills (use of pencil, triangle, etc.) and a drafting discipline. However, it is commonly agreed upon that CAD will become the primary drafting tool with manual skills developed only as backup. Therefore, educators are advised to take a different approach.

One approach is to establish competency in a drafting discipline using computers instead of drawing boards. In this setting, CAD skills are developed along with the drafting skills. Assignments are given in sequence of developing conceptual drafting skills (e.g. orthographic projection, section views, floor plans, electrical schematic); however, the assignment is completed only on a CAD system. No manual skills are used from the beginning of the course.

Another approach is to establish elementary competency in a drafting discipline using freehand sketching, then utilizing CAD and manual skills for industrial quality work. Much of the fundamental drafting concepts do not require the precision of drafting tools. Visual perception is best learned using freehand sketching as the student is not limited to the tools and can experiement both in and out of the classroom. Usually home-work in a drafting couse is unheard of. This approach makes better use of class time as drill and practice is done outside the classroom.

The selected method rests on the strategy chosen by the teacher; however, as with most coursework, there are prerequisite skills which the student is advised to possess before using a CAD system.

Prerequisite Skills

The respondents of Nielsen's 1985 study of CAD users indicated three skill areas to be developed either before or during experience with computer-aided design. These are 1) basic programming, 2) trigonometry, analytic geometry, and 3) a drafting discipline.

The student's capability to program in basic is not as important as the general operating skills learned during the introduction to microcomputers. When using a CAD system the student does not need to know a programming language, but must be able to operate the computer and peripheral equipment. It is also helpful for the student to have a fundamental understanding of how a microcomputer works so that they can identify the advantages of a CAD system resulting from the speed and capacity of the computer.

Trigonometry and analytic geometry form the basis for use of absolute, relative and polar coordinate systems relied on when using a CAD system. Since geometric construction on a CAD system is utilizes the mind more than the hands, math skills are stressed. This recommendation does not refer to an in depth study of trigonometry, rather an orientation to basic trigonometry equations.

As stated before, a foundation in a drafting discipline is necessary for a student to apply the tools of drafting. The drafting skills and CAD skills may be developed concurrently. This eliminates "lettering for the sake of lettering" or "linework for the sake of linework" and makes drafting work relevant to the field of study.

Competencies

In research done by Greg Peck of the Mexico, Missouri Vocational-Technical Center with the help of industrial CAD users and CAD educators, the consensus was that "priority be given to those features that make CAD

efficient and not hardware dependent features such as back-ups and plotting that vary greatly from one system to another (Peck, 1984:14). Although commands differ in syntax, features which are common among CAD systems include:

1. system operation (login/logout, file retrieve/save, plotting)
2. coordinate systems (absolute, relative, polar)
3. screen scales, magnification
4. entity creation (drawing lines, circles, arcs, fillets)
5. entity modification (erase, move, trim)
6. text (selecting style, inserting, modifying)
7. dimensioning (automatic, semi-automatic, vertical, horizontal, radial)
8. drawing aides (grids, object snap, orthogonal mode)
9. windowing (selecting a portion of the screen to work with)
10. layer selection (place parts on different levels of a drawing)
11. copy (make multiple copies of a part or group of parts)
12. mirror (make copies of symmetrical objects around an axis)
13. grouping (making multiple entities belong together)
14. symbol library (storing and recalling often used symbols and parts)

Depending on the program, these skills may be the only competencies required of the student; however, a vocational program will require a deeper understanding of CAD and especially its relationship to the manufacturing, construction, and electronics industries. Pedras and Hoggard (1985) developed a DACUM chart illustrating the specific duties and tasks performed by a Computer Drafting Technician. This chart, as illustrated in figure 1, is not drafting discipline specific but rather builds on a present knowledge of drafting principles.

CLARK COUNTY COMMUNITY COLLEGE
DACUM OCCUPATIONAL ANALYSIS
COMPUTER DRAFTING TECHNICIAN

Definition: Computer Drafting Technician

A trained drafter who must combine conventional drawing skill, theory and methods with the appropriate use of a CAD system. The specialist must be able to operate a basic CAD system, execute drawing assignments, change and execute detailed drawings, and prepare final drawings.

I Utilize Computer	Log on off system	Select appropriate program	Utilize appropriate input/output device	Operate key-board proficiently	Maintain proper environment				
II Manage Library of Symbols	Create and maintain symbol index	Create and use symbols	Create and use symbol menus						
III Interpret Design Criteria	Establish job and task scope	Interact with design team	Plan approach	Establish time frame					
IV Prepare Preliminary Drawing	Identify components	Create data base file	Set screen/drawing parameters	Lay out the drawing	Utilize symbols	Utilize text	Select key dimensions	Produce check prints	Obtain approvals
V Prepare Finished Drawings	Finalize drawing parameters	Modify drawing to conform to standards	Select final dimensions	Incorporate reference data and standard notations	Select output parameters		Prepare finish check print	Produce final drawing	
VI Maintain Support Files	Create and maintain drawing index	Create and maintain drawing files	Implement security procedure for protection of file media	Implement appropriate back-up procedure					
VII Exploit System's Maximum Capabilities	Learn system capabilities	Communicate system capabilities	Apply knowledge to achieve maximum proficiency						
VIII Troubleshoot System Problems	Identify problem	Document problem	Resolve minor problems	Refer to appropriate help sources					
IX. Must Remain Current in Field	Participate in user groups	Access vendor updates	Participate in professional associations	Continue education	Use current publications				

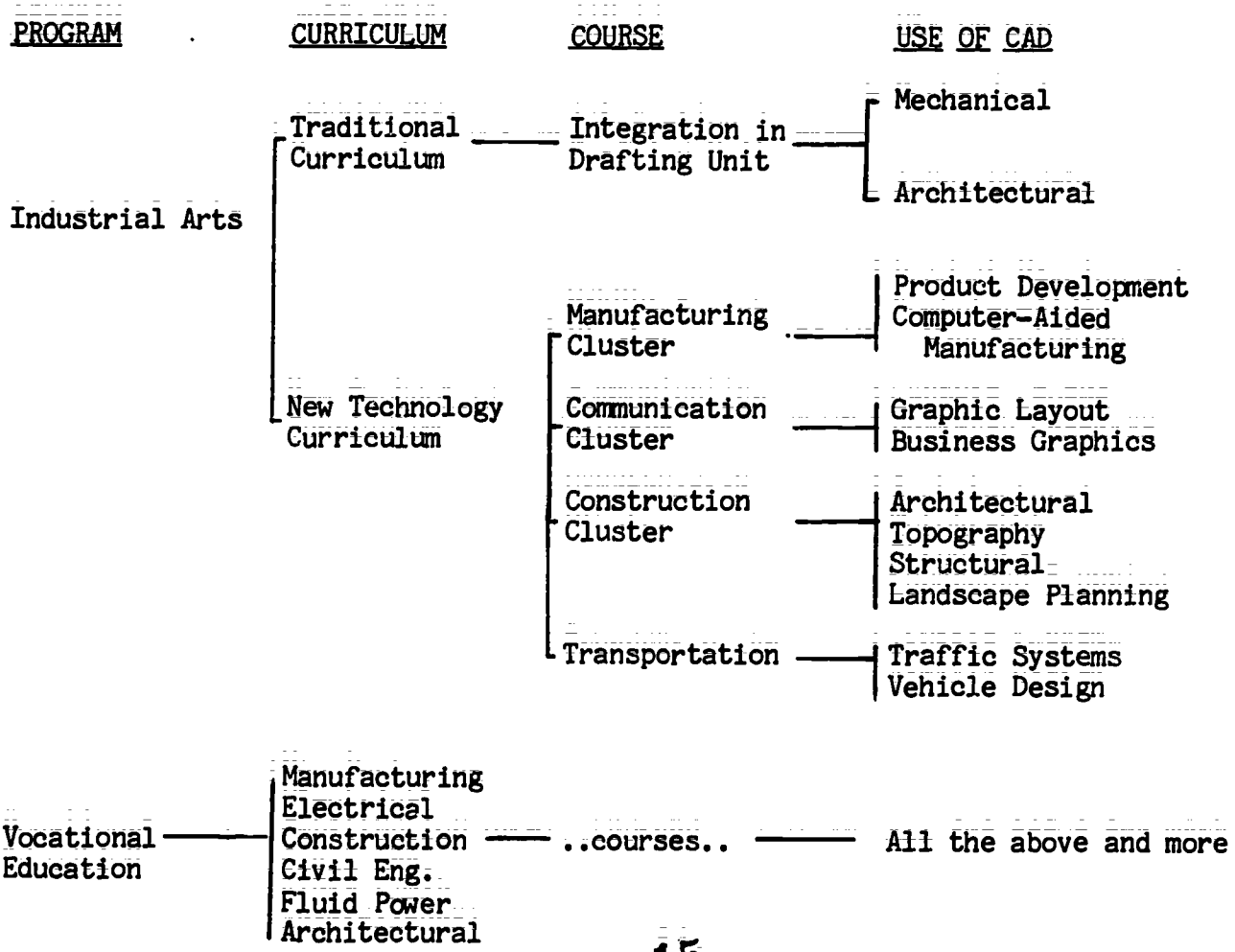
Figure 1

Program Area

There are many different areas in which a teacher could implement a CAD system. The area of emphasis is dependent on the particular objectives of the curriculum. Are the students being prepared for job entry skills? Is the program an introduction to technology? Figure 2 illustrates a sample breakdown of differing industrial education programs and the placement of a CAD system in those programs.

Figure 2

Program Areas of CAD



The new emphasis on technology programs in the secondary curriculum offers a great opportunity to use a CAD system in a manufacturing or construction cluster. Recommendations made by industrial CAD users in Nielsen's 1985 study emphasized diverting away from a "paper" approach toward the "electronic age" and toward computer aided and computer integrated manufacturing . The Chrysler films noted in Appendix A provide a picture of CAD use in the industrial environment.

CONCLUSION

This paper has brought to light the many considerations encountered during the process of integrating computer-aided design into the industrial education curriculum. It is the responsibility of industrial educators to maintain abreast of current technology and incorporate emerging industrial techniques into the classroom.

Incorporating CAD becomes more a reality as the price of CAD software and computer hardware decrease. With careful consideration of equipment already owned by the school system and prudent budgeting techniques, even small school systems are given the the opportunity to display to students the latest technologies.

The methodology used in teaching drafting using traditional tools is not any different when using computer-aided design. A tool is a tool. The depth in which CAD is covered depends on the level of the student and the objectives of the program.

Our students deserve to be exposed to systems which affect the productivity of modern industry.

REFERENCES

Bertoline, Gary R. Fundamentals of CAD. Albany NY: Delmar Publishers, 1985.

Bureau of Vocational Technical and Adult Education. Drafting Competency Based Curriculum. West Virginia: West Virginia Department of Education, 1977.

Getsch, David L. The CAD/CAM Workbook. Cincinatti: South-Western Publishing Co., 1983.

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Hart, Glenn. CAD: The Big Picture for Micros." PC Magazine. March 11, 1986.

Milwaukee Area Technical College. Student Workbook for MATCCAD.

Nielson, Arthur L. Education/Industry "Linkages": A Survey of CAD Users. Indiana State University, 1985.

Peck, Greg. Competency Based Computer Aided Drafting Curriculum for Vocational Drafting. Mexico, Missouri: Mexico Vocational Technical Project 84-131/132-600-2(004-119)(E), 1984.

Pedras, Melvin J., David Hoggard. "A Suggested Computer Aided Drafting Curriculum (DACUM Based)." Paper Presented at the American Vocational Education Association Annual Conference, 1985.

Schwendau, Mark. "CAD Materials for Course and Reference Use." School Shop. August, 1984.

T & W Systems, Inc. Tutorial Workbood for CAD APPLE.

Thorsen Richard S., Lee, Mansuk., Wei, Chih. "The Roles of Microcomputers and Mainframe Computers in University Responses to Industry CAD/CAM Needs." ASEE Annual Conference Proceedings, 1985.

Voisinet, Donald. "CAD--Sell the Sizzle, Not the Steak." Technical Education News. Fall, 1985.

Weber, Tony. CAD Questions. Gregg/McGraw Hill, 1984.

Wohlers, Terry. "Experimental CAD Course Uses Low Cost Systems." T.H.E. Journal. October, 1984.

Woodman, Josef. "Classroom CAD Comes to Age." The Computer Instructor. May, 1985.

Zandi, M. Computer Aided Design and Drafting. New York: Delmar Publishers, Inc., 1985.

_____. "Directory of Microcomputer CAD." T.H.E. Journal. June, 1986.

Appendix A

COURSE MATERIALS

Textbooks

CAD/CAM With Personal Computers
Patrick R. Carberry
Tab Books, Inc.
Blue Ridge Summit, PA 17214

Computer Aided Design and Drafting
M. Zandi
Delmar Publishers Inc.
2 Computer Drive West
Box 15015
Albany, NW 12212-5015

Fundamentals of CAD
Gary Bertoline
Delmar Publishers
2 Computer Drive West
Box 15015
Albany, NW 12212-5015

Introduction to CAD
Donald Voisinet
Gregg/McGraw Hill
Princeton Road
Hightstown, NY 08520

The CAD/CAM Workbook
David L. Goetsch
The CAD/CAM Filmstrips
South-Western Publishing Company
355 Conde Street
West Chicago, IL 60185

Architectural CAD Lab Manual
Thomas Obermeyer
Gregg/McGraw Hill
Princeton Road
Hightstown, NY 08520

Applying AutoCAD
Terry T. Wohlers
Glencoe Publishing
17337 Ventura Boulevard
Encino, California 91316

Mechanical CAD Lab Manual
Donald Voisinet
Gregg/McGraw Hill
Princeton Road
Hightstown, NY 08520

CAD Appications: Mechanical
Gary Bertoline
Delmar Publishers
2 Computer Drive West
Box 15015
Albany, NW 12212-5015

CAD Applications: Architectural
David L. Goetsch
Delmar Publishers
2 Computer Drive West
Box 15015
Albany, NW 12212-5015

CAD Applications: Electronics
Gerald R. Hansen, Elwood V. Hathaway
Delmar Publishers
2 Computer Drive West, Box 15015
Albany, NW 12212-5015

CAD/CAM Compuater Aided Design & Drafting
Mikell Groover, Emory Zimmers, Jr.
Prentice-Hall, Inc.
Englewood Cliffs, N.J. 07632

Using AutoCAD
James E. Fuller
Delmar Publishers
2 Computer Drive West
Box 15015
Albany, NW 12212-5015

Introduction to Computer Aided Drafting
David Goetsch
Prentice-Hall, Inc.
Englewood Cliffs, N.J. 07632

Media

Computer Aided Design, 1172, $6
CAD/CAD Curriculum, #A-58, $15
American Vocational Association
2020 North 14th Street
Arlington, VA 22201

CAD Computer Aided Design Explained
3 filmstrips/cassettes 860-V3, $125
Bergwall Productions
106 Charles Lindbergh
Uniondale, NY 11553

CAD Ventures Unlimited
CAD/CAM, filmstrip/cassette,
M 6354, $35
Career Aids Inc.
8950 Lurline Avenue
Chatsworth, CA 91311

CAD/CAM Basics
80 color slides, $103
DMR Associates
P.O. Box 255A
West Gordon, MA 01472

Microcomputer CAD
VSH videotape, $60
Hollywood Video
5 East Lee Street
Plano, IL 60545

Commitment to the Future
16 mm movie
The Innovators, 16mm movie
158 Carmen Drive
Elk Grove Village, IL 60007

"The Challenge of Manufacturing"
16 mm Movie, $185
Modern Talking Picture Service, Inc.
5000 Park St. North
St. Petersburg, FL 33709

"Just in Time"
16 mm Movie, free loan
Modern Talking Picture Service, Inc.
5000 Park St. North
St. Petersburg, FL 33709

"For Years to Come"
16 mm Movie, free loan
Modern Talking Picture Service, Inc.
5000 Park St. North
St. Petersburg, FL 33709

CAD/CAM Technology
Filmstrips, $210; slides $79; video $89
Meridian Education Corporation
205 E. Locust St.
Bloomington, IL 61701

Computer Aided Drafting
Video, $219; free preview
Vocational Media Associates, Prentice-Hall
P.O. Box 1050
Mount Kisco, NY 10549

The CAD/CAM Filmstrips
4 Filmstrips, 2 Cassettes, $195
South-Western Publishing Co.
5101 Madison Road
Cincinatti, OH 45227

Directories, Periodicals

A Survey Low Cost Systems
Leading Edge Publications
317 Forest Central Two
11551 Forest Central Drive
Dallas, TX 75243

The Anderson Report
P.O. Box 3616
Simi Valley, CA 93063

CAD/CAM Alert
822 Boylston Street
Chestnut Hill, MA 02167

The CAD/CAM Digest
Productivity International
5622 Dyer Street, Suite 220
Dallas, TX 75206

The CAD/CAM Handbook
Computervision Corporation
201 Burlington Avenue
Bedford, MA 01730

The CAD/CAM Industry Directory
Contract Technical Database Corp.
PO Box 720
Conroe, TX 77305

Computer-Aided Design Report
841 Turquoise Street
Suite D & E
San Diego, CA 92109

Computer Design
119 Russel Street
Littleton, MA 01460

Computer Graphics News
2033 M Street, N.W., Suite 330
Washington, D.C. 20036

Computer Graphics World
PO Box 122
Tulsa, OK 74101

Automation News
CAD/CIM/CAM Technology
Computer Aided Engineering
Computer Graphics News
Computer Graphics World
Industrial Education

Design News
270 St. Paul Street
Denver, CO 80206

Digital Design
1050 Commonwealth Avenue
Boston, MA 02215

Engineering Design Graphics Journal
2070 Neil Avenue
Columbus, OH 43201

Engineering News Record
PO Box 516
Highstown, NJ 08520

High Technology
PO Box 5239
Boulder, CO 80322

Machine Design
Penton Plaza
Cleveland, OH 44114
Plan and Print
10116 Franklin Avenue
Franklin Park, IL 60131

The S. Klein Newesletter on Computer Graphics
730 Boston Post Road, PO Box 89
Sudbury, MA 01776

Computer Graphics: U.S. Directory of Vendors
Daratech, Inc.
16 Myrtle Ave.
P.O. Box 410
Cambridge, MA 02138

Design Drafting and Reprographics
390 Fifth Avenue
New York, NY 10018

Designfax
6521 Davis Industrial Parkway
Solon, OH 44139

Appendix B

EVALUATION OF CAD SYSTEM

Evaluator _____

System a: _____ Vendor: _____

System b: _____ Vendor: _____

System c: _____ Vendor: _____

	System a	System b	System c
Entity Draw Commands			
Line			
Auto line closing			
Continuation			
Wide lines			
Parallel lines			
Line types			
Number of line weights			
Mix line types on one layer			
Mix color on one layer			
Point/node			
Circle			
Center/radius			
Center/diameter			
3 point			
2 point			
Arc			
3 point			
Center,radius radians			
other _____			
Ellipse			
Multipoint curve			
Rectangle			
Rounded rectangle			
Square			
Polygons			
Polylines			
Solid areas			
Arrows			
Text			
Centering			
Auto-aligned			
Font changes			
Rotation			
Boldface			

Drawing assistance

- Snap
  - Variable sizing
  - Rotation
  - Isometric
  - Angle
  - Align
  - Aspect
- Grid
  - Variable sizing
  - Aspect
- Axis
  - Variable sizing
  - Aspect
- Orthogonal mode
- Object snap
  - Nearest
  - Endpoint
  - Midpoint
  - Center of circle
  - Node/point
  - Quadrant of circle
  - Intersection
  - Perpendicular
  - Tangent
  - Polar

Editing Commands

- Selection
  - Groups of objects
  - Individual objects
  - Windows
  - Multiple Windows
  - Last object
  - By entity type
- Erase
- Unerase
- Move
- Copy
- Mirror image
- Rotation
- Endpoint join
- Resizing
- Layer change
- Area fill
- Break/trim
  - Lines
  - Circles/arcs
- Fillet
- Chamfer
- Arrays
  - Rectangular
  - Circular
- Segment line/arc

Inquiry commands

- List charactreristics
- Calculate distances
- Calculate areas
- Calculate volume
- Calculate moments

Display controls

- Zoom
  - Specity magnification factor
  - Window
  - Nesting/return
- Pan
- Visible coordinates
- Visible dimensions
- Change limits
- Change unit base
- Named views
- Solid fill control
- Object dragging
- Isometric drawing
- Cross sectioning
- Projections

Layers

- Number of layers
- Color of layer
- Named layers

Dimensioning

- Linear
- Angular
- Diameter
- Radius
- Extension lines
- Tolerances
- Leaders
- Center marks
- Horizontal
- Vertical
- Aligned
- Rotated
- Baseline
- Continue/chained

Blocks

- Define from active file
- Saved on disk
- Size scaling on insertion
- Rotation on insertion

Hatching

- Number of patterns
- User defined patterns
- Hatching styles

Attributes

- Visible/invisible
- Editable
- other _____
- other _____

Help

- On screen
- Context sensitive
- Disk tutorial

Plotting controls

- Variable sizing
- Pen speed control
- Pen force control
- Pen acceleration control
- Plot rotation
- Automatic scaleing
- Exact scaling
- Spooling
- Plotter optimization

Miscellaneous commands

- Command scrips
- Slide shows
- Programming language
- User defined screen menus
- Tablet menues
- Freehand sketching
- 3 dimensional
- DOS type commands
- Execute DOS within CAD
- Symbol library
- Metrification of dimensions
- Size restrictions on plotter
- Bill of material generation
- Networking capabilities

APPENDIX C

MICROCOMPUTER CAD SOFTWARE VENDORS

A June 1986 survey of microcomputer CAD systems for education conducted by the staff of the Technical Horizons in Education Journal uncovered thirty such systems. The survey requested important information as operating system used, design capabilities, peripheral devices, and price. The list, as it appears in the June 1986 edition of T.H.E. Journal, appears on the following four pages.

Systems not covered by the T.H.E. Journal appear below.

COMPANY/SOFTWARE	EQUIPMENT/COST
BG Graphics System, Inc. Drawing Processor 824 Stetson Avenue Kent, WA 98031	IBM PC and compatibles Cost: $1,000
Datagraphics CAD Master 7011 Biscayne Milford, MI 48042	IBM PC Cost: $1,100-$1,800 Excellent drafting capability
Metasoft Corporation Benchmark 6509 West Frye Road Chandler, AZ 85224	IBM PC and compatibles Cost: $600 Introductory Package
Micrographix PC-Draw 1701 North Greenville Richardson, TX 75081	IBM PC and compatibles Cost: $250 Very basic package
Personal CAD Systems CADplan and CADdraft 15425 Los Gatos Boulevard Los Gatos, CA 95030	IBM PC and compatibles Cost: $500-$1,300 Entry level or introductory Package

Directory of Microcomputer CAD Systems for Education

The following companies responded to a survey conducted by T.H.E. JOURNAL. Each manufacturer was asked to provide information on two CAD systems. This directory is not intended to be comprehensive, and a product listing does not imply an endorsement. *(See Technology Update, page 12.)*

Software/ Manufacturer	Operating System(s)	Design Capabilities	Special Capabilities	No. of Layers	No. of Colors	Recommended RAM	Disk Drive Configuration	Graphics Hardware	Input Devices Supported	Price
Schematic Entry Advanced Engineering Solutions, Inc. 75 Manhattan Drive Suite 302 Boulder, CO 80303 (303) 499-2910	Macintosh	Grid, snap, text, zoom, windowing, design database	Netlist translators to Scicards, Gerber, Calay, Computervision; written in Modula-2			512K	External floppy disk drive required		Digitizer, mouse, keyboard	$700*
AutoCAD Autodesk, Inc. 2320 Marinship Way Sausalito, CA 94965 (415) 332-2344	MS-DOS, UNIX	2D, 3D, AI capability, grid, snap fitted curves, text, zoom, pan, rotation, windowing, freehand sketching, polylines, splines	Hidden-line removal; user-definable macros; interfaces available for CNC machines; supports C and LISP	Unltd.	Unltd.	512K	Hard disk recommended	Graphics card	Digitizer, mouse, keyboard, joystick	Contact your local AutoCAD dealer*
Cadkey, 3D V2.0 Brodhead-Garrett Co. 4560 E. 71st St. Cleveland, OH 44105 (216) 341-0248	DOS 2.0 or higher	2D, 3D, grid, snap, text, zoom, windowing	Mesh generation; projected tangencies in true 3D; off-line plotting; written in C; IGES translator available for mainframe or CAM connection	256	16	640K	One floppy, one hard disk	High-resolution monochrome or color monitor	Digitizer, mouse, keyboard	$2,695; $495 for eight or more
CADillac-M CAD Technologies 5225 Old Orchard Road Suite 4 Skokie, IL 60077 (312) 967-8900	MS-DOS	Same as AutoCAD plus mechanical designers	Ancillary to AutoCAD						Digitizer	$590*
CADVANCE CalComp Personal Systems Unit 200 Hacienda Ave. Campbell, CA 95008 (408) 866-6272	MS-DOS	2D, 3D, grid, snap, fitted curves, text, zoom, pan, rotation, windowing, DXF, IGES	Cleans up parallel line (architectural wall) intersections; moves vertices to stretch walls; supports four foreign languages	127	16	512K	10M hard disk	320x200 (minimum) graphics card	Digitizer, mouse, keyboard	$2,500*
CADlab Cascade Graphics Systems 16842 Von Karman Ave. Irvine, CA 92714 (714) 474-6200	Apple IIe, IBM PC, XT	2D, grid, snap, text, zoom, windowing, mirroring, step-repeat	Eight discipline-specific libraries; two-digit drawing functions; supports C-BASIC and UNIX	256	8	256K	One or two double-sided disk drives	624x1,024 monochrome or color monitor	Digitizers, light pens, keyboards, joysticks, scanners	$1,000-$1,500*
microCADDS Computervision Corp. Personal Systems Business Unit 2 Crosby Drive Bedford, MA 01730 (617) 275-1800	PC-DOS 2.1 or higher	2D, 3D, grid, snap, fitted curves, text, zoom, pan, rotation, windowing, stretch, trim, divide	3D wireframe and surface modeling; drawing production to engineering standards; written in UPL	255	16	512K	10M hard disk, 20M preferred	Advanced graphics card	Keyboard, tablet or on-screen menus	$5,800 for Geometric Construction and Detailing; $2,800 for Surfaces*

*Educational discounts available

Software/ Manufacturer	Operating System(s)	Design Capabilities	Special Capabilities	No. of Layers	No. of Colors	Recommended RAM	Disk Drive Configuration	Graphics Hardware	Input Devices Supported	Price
Models 912 and 920 Integrated Imaging Systems Datacopy Corp. 1215 Terra Bella Ave. Mountain View, CA 94043 (415) 965-7900	PC-DOS and WIPS EDITOR software	Turnkey systems that allows the user to scan existing drawings and feed them into AutoCAD; includes 3D, text, zoom, rotation, windowing	WIPS EDITOR (Word Imaging Processing Software) has editing and drawing capabilities			640K			Digitizer, power supply, lights all included in system	
EmcoCam Emco Maier Corp. 2050 Fairwood Ave. Columbus, OH 43207 (614) 445-8328	MS-DOS 2.0 or higher	CAD/CAM: 2D, text, zoom, pan, rotation, windowing	Ancillary to AutoCAD	8	8	512K	Two 230K disk drives minimum, or one 360K disk drive and one 5M hard disk	Color graphics card and monitor	Digitizer	$2,250
Generic CADD Generic Software, Inc. 8763 148th St. NE Redmond, WA 98052 (206) 885-5307 (800) 228-3601	PC-DOS 2.0 or higher	2D, grid, snap, text, zoom, rotation, windowing, mirroring, stretching, shrinking	User-defined video and digitizer menus; Auto-Convert package transfers files to and from AutoCAD	256	256	512K-640K	Two 360K floppy disk drives or one floppy disk drive and one hard disk	Graphics card and matching monitor	Digitizer, mouse	$99
PC-GRASP GRASP, Inc. RD3 Box 233A Troy, NY 12180 (518) 279-9414	DOS 3.1 and VDI device drivers	CAD/CAM: 3D, text, zoom, rotation, windowing	Allows the modeling and multi-image display of a one to six jointed robot; simulation		8	512K	Hard disk	Professional graphics controller	Mouse optional	$2,500
discoverCAD Hearlihy & Co. 714 W. Columbia St. P.O. Box 869 Springfield, OH 45501 (800) 622-1000 (513) 324-5721	Apple IIe or IIc, DOS 3.3	2D, grid, snap, text, zoom, pan, rotation, windowing, freehand sketching, automatic dimensioning mirroring	Support for NC host processors, adjustable grid and snap; written in PASCAL	128		128K	Two floppy disk drives	Monochrome monitor and Apple Super Serial Card	Mouse, keyboard	$209 for schools
CADDRAW Hearlihy & Co. 714 W. Columbia St. P.O. Box 869 Springfield, OH 45501 (800) 622-1000 (513) 324-5721	Apple II+, IIe or IIc, DOS 3.3	2D, 3D, grid, snap, text, rotation, windowing, freehand sketching, automatic centering	Support for NC host processors; point-by-point plotting of solid and hidden lines at any thickness; written in Applesoft BASIC	2	8	64K, 48K on the II+	One floppy disk drive	Monochrome or color monitor	Keyboard	$123 for schools
CAD/BASIC Kern International, Inc. 575 Washington St. Pembroke, MA 02359 (617) 826-0095	MS-DOS or PC DOS 1.1 or higher	2D, grid, fitted curves, text, zoom, pan, rotation	Semi-automatic dimensioning, written in BASIC			64K	One floppy disk drive	Graphics card	Keyboard	$120*
DESIGNER 3D Kern International, Inc. 575 Washington St. Pembroke, MA 02359 (617) 826-0095	MS-DOS or PC-DOS 1.1	3D, fitted curves, text, zoom, pan, rotation	30 curve fitting; source code included; written in BASIC	10		64K	One floppy disk drive	Graphics card	Keyboard	$120
Designfile Lovelace-Lawrence & Co. 18 Broad St. Charleston, SC 29401 (803) 577-7838	MS-DOS, Modua 2	AI capability, graphics file manager	Classification and coding for parts and assemblies for CAD design libraries.			128K			Keyboard, mouse	$5,000-$15,000, available in modules

*Educational discounts available

Software/ Manufacturer	Operating System(s)	Design Capabilities	Special Capabilities	No. of Layers	No. of Colors	Recommended RAM	Disk Drive Configuration	Graphics Hardware	Input Devices Supported	Price
MATC-CAD MATC-CAD 1015 N. Sixth St. Milwaukee, WI 53203 (414) 278-6743	Apple or IBM PC	2D, grid, snap, text, zoom, rotation, windowing	Instructor and student materials set up in a suggested curriculum, including tests, exercises and answers; written in PASCAL	256		64K (Apple), 256K (IBM)	Two disk drives	Apple graphics tablet (Apple), Kurta tablet (IBM)	Keyboard, joystick	$500
Design Board Professional Mega CADD, Inc. 401 Second Ave., South Seattle, WA 98104 (206) 623-6245	MS-DOS	3D, grid, snap, zoom, pan, rotation, windowing, curved surfaces	Unlimited perspectives; isometric and orthographic views; automatic hidden line removal; link to 2D drafting software; written in FORTRAN		2	512K	Two floppy disk drives or hard disk	Graphics card	Digitizer, mouse	$1,750*
Design Board Illustrator Mega CADD, Inc. 401 Second Ave., South Seattle, WA 98104 (206) 623-6245	MS-DOS	Grid, snap, fitted curves, text, zoom, pan, rotation, windowing, freehand sketching	Paint, animation and slide shows; CADD enhancement and presentation; written in FORTRAN		256	256K	Two floppy disk drives or hard disk	Graphics card	Digitizer, mouse	$395*
MEGASYSTEMS 32000 Megasystems 2741 W. Southern Suite 24B Tempe, AZ 85282 (602) 438-0954	MS-DOS 3.1 or higher	Workstation and file server that runs AutoCAD in a network configuration	MEGANET networking software runs Lotus 1-2-3, dBASE, WordStar			512K-640K	10M hard disk on file server	Supports Autodesk peripherals	On-screen touch digitizer	$3,800*
MICAD-SE, MICAD-CRM MiCAD Systems, Inc. 419 Park Ave. South New York, NY 10016 (212) 213-9350	MS-DOS	2D, 3D, AI capability, grid, snap, fitted curves, text, zoom, pan, rotation, windowing, freehand sketching	Ancillary to AutoCAD	Unltd	16	640K	Hard disk	Graphics card and monitor	Digitizer	$5,000 and up
CADKEY Micro Control Systems, 27 Hartford Turnpike Vernon, CT 06066 (203) 647-0220	MS-DOS Inc.	CAD/CAM: 2D, 3D, grid, snap, fitted curves, text, zoom, pan, rotation, windowing, freehand sketching	Unlimited number of views; 3D splines: x, y and z axes: all views simultaneously updated; written in C	256	16	512K		Graphics card, monitor	Mouse, keyboard, 2D tablet	$495 for schools
In•a•Vision Micrografx, Inc. 1820 No. Greenville Ave. Richardson, TX 75081 (214) 234-1769	MS-DOS 2.0 or higher, or Microsoft windows	2D, grid, snap, text, zoom, pan, rotation, windowing, freehand sketching, mirroring	Undo feature; different line widths and styles; crosshairs; user-definable rulers; written in C	16	8	320K	Hard disk	Graphics adapter (IBM EGA required for color)	Mouse, keyboard, light pen, joystick	$495*
CAD-2 Robo Systems 111 Pheasant Run Newtown, PA 18940 (215) 968-4422	AppleDOS	2D, grid, snap, text, zoom, rotation, freehand sketching		Unltd		128K	Two floppy disk drives	Complete Apple IIe system	Joystick controller	$1,320
ROBOCAD-PC Robo Systems 111 Pheasant Run Newtown, PA 18940 (215) 968-4422	MS-DOS or PC-DOS	2D, grid, snap, fitted curves, text, zoom, pan, rotation, freehand sketching	Partial erase, partial change, fillet, tangent, radial snap grid, orth lock, angle lock			640K	Two floppy disk drives or one floppy disk drive and one hard disk	Graphics card, monochrome monitor	Digitizer, mouse	$1,495

*Educational discounts available

Software/ Manufacturer	Operating System(s)	Design Capabilities	Special Capabilities	No. of Layers	No. of Colors	Recommended RAM	Disk Drive Configuration	Graphics Hardware	Input Devices Supported	Price
VersaCAD Advanced T & W Systems 7372 Prince Drive Huntington Beach, CA 92647 (714) 847-9960	MS-DOS, UNIX	2D, grid, snap, fitted curves, text, zoom, pan, rotation, windowing, freehand sketching	Multi-line draw (up to 250); 3D isometric views; automatic break; cut and paste; fillet, curve and dimension	250	256	640K	Two floppy disk drives or one hard disk	Graphics card	Digitizer, mouse, keyboard	$2,495*
CADAPPLE 3.0/3.5 T & W Systems 7372 Prince Drive Huntington Beach, CA 92647 (714) 847-9960	MS-DOS, UNIX	2D, 3D, grid, snap, text, zoom, rotation, windowing	Symbol libraries	250	16	64K (3.0), 128K (3.5)	Two floppy disk drives	Built in	Digitizer, mouse, joystick	$1,495*
SuperCads Tasvir Corp. 1091 Stierlin Road Mountain View, CA 94043 (415) 964-7000	XENIX V	2D, 3D, grid, snap, fitted curves, text, zoom, pan, rotation, windowing	Model mode; drawing mode; figure capabilities; full graphic editing; written in C	256	4,096	2.9M	1.2M hard disk	Graphics card	Digitizer, keyboard	$18,900 PC/AT turnkey system
Auto Word Plus Technical Software, Inc. 28790 Chagrin Blvd. Cleveland, OH 44122 (216) 765-133	MS-DOS	Text, automatic scheduling generation	Ancillary to AutoCAD; works with any ASCII file; translates text files from word processor into AutoCAD drawing			64K	One floppy disk drive or one hard disk	None required	None required	$150*
3-D GRAPHIXX Universal Intergraphix Corp., 2990 E. G Street Suite 108 Ontario, CA 91764 (714) 989-3992	MS-DOS or PC-DOS 2.x and 3.x	2D, 3D, grid, snap, fitted curves, text, zoom, pan, rotation, windowing, freehand sketching	Real-time animation; slide shows; libraries; line and planes intersect planes; auto dimensioning; z-axis can be drawn anywhere; written in C	256	16	640K	10M hard disk	IBM CGA graphics adapter and compatible monitor	Digitizer, mouse	$3,995*

*Educational discounts available